it. Thus the same alloy, without being melted, can by heating and chilling have all pattern removed, and by reheating, followed by a not very rapid cool, the pattern can be restored. The constancy in the size of the polygons points to their having been formed at an earlier period in the history of the alloy.

We see from the above that the patterns of slowly cooled copper-tin alloys are, at all events until they have been confirmed by the examination of chilled portions, entirely misleading as to the separations that occurred during solidification. Even the evidence for the existence of the compound Cu_3Sn will have to be revised; although in a somewhat altered form it will probably be found to be satisfactory.

We hope shortly to present to the Royal Society a more complete account of these alloys.

"On the Enhanced Lines in the Spectrum of the Chromosphere." By Sir NORMAN LOCKYER, K.C.B., F.R.S., and F. E. BAXANDALL, A.R.C.S. Received March 19,—Read March 28, 1901.

In the recently published account* of the spectroscopic results obtained by members of the expedition from the Yerkes Observatory, during the solar eclipse of May 28th, 1900, although the record of the wave-lengths of the lines photographed on the different eclipse plates is of great value, exception must be taken to the method of assigning origins to the lines. This question is so important just now that it is desirable to deal with it without delay. The only origins which Professor Frost appears to accept are those given by Rowland to any moderately strong solar line which agrees in position, either exactly or very nearly, with an eclipse line. In discussing the eclipse lines he has made specific allusions to the "enhanced" lines of some of the metals, and to their relationship—or non-relationship—to the eclipse lines.

On p. 347 he says, "These plates give no evidence of any relationship between the bright lines and the 'enhanced' lines, or lines distinctly more intense in the spark than in the arc spectrum, although Sir Norman Lockyer has attached much significance to a supposed connection between them. Some of the enhanced lines are present and some are not, or at least were not conspicuous enough for measurement." In the paragraph immediately following, he says, "In case of titanium, for which Lockyer gives 48 enhanced lines within our limits, we may summarise the comparison as follows: 17 lines do

* Frost, 'Ast.-Phys. Journ.,' vol. 12, p. 307, 1900.

not appear as bright on the eclipse plates; one pair is doubtful, the remainder occur as quite strong lines of the ordinary dark line spectrum, and hence would be expected to appear in the reversing layer, as they do."

If a difference of 0·3 tenth-metre be allowed between the wave-length of an eclipse line and that of the possibly corresponding metallic line (and in some cases Professor Frost accepts a difference of 0·35 or more between his adopted wave-length and Rowland's solar wave-length), the seventeen lines above mentioned dwindle down to ten. That leaves, then, thirty-eight out of forty-eight of the enhanced lines, or about 80 per cent., which agree in position within 0·3 tenth-metre with the eclipse lines. Surely this shows as close a relationship between the enhanced lines of titanium and the eclipse lines, as that between the latter and the stronger of the Fraunhofer lines, for it is stated on p. 345, "of 171 of Rowland's lines, 61 per cent. were measured as bright on the plates."

Nowhere has it been contended that the whole set of enhanced lines belonging to any one metal are represented in the spectrum of any one celestial body; what has been stated is that the enhanced lines of some of the metals are, in general, of paramount importance in the spectra of some stars (*e.g.*, α Cygni), specially prominent in others (*e.g.*, γ Cygni, the spectrum of which, with the exception of the absence of helium lines, very closely resembles that of the chromosphere), and are a marked feature of the spectrum of the chromosphere itself.

Professor Frost either has not noticed, or does not point out, that most of the enhanced lines of titanium, as compared with the ordinary lines of that element, are specially prominent, and are amongst the lines of greatest intensity in his list, as shown in the following table. The first two columns of the table contain respectively the wave-lengths and intensities of Rowland's solar lines (in the region covered by the eclipse lines), which have an intensity of 2 or more, and which have been ascribed to Ti only. Double assignations, of which Ti forms one, have been omitted, as it is difficult, if not impossible, to determine what proportion of the intensity of the solar line is due to each element. The third column indicates whether the titanium line at the given wave-length is an enhanced one or not. The fourth gives the wave-lengths, the fifth and sixth the intensities, and the eighth the origins which Professor Frost has adopted for the corresponding eclipse lines, and the seventh the intensities of the lines reduced from the Kensington eclipse photographs. To make them roughly comparable with Professor Frost's, these intensities have been multiplied by ten throughout, as 1 is adopted for the weakest lines in the Kensington photographs, whereas he adopts 10 for lines just visible.

Solar Lines of Intensity 2 or greater, ascribed by Rowland to Ti only.

Solar – Ti lines λ (Rowland).	Int. in sun.	If enhanced line.	Eclipse.					Remarks.
			Frost.			Kensington.	Frost's origin.	
			Adopted wave-length.	Intensity. Max. 500. Prism spectra. "Flash" II.	Cusp II.	Int. Max. 100.		
4028·50	4	yes	4028·28	35	20	25		Eclipse line undoubtedly due to Ti.
4078·63	3	no	4078·6	15	—	—	Fe, Ti	
4171·21	4	no	4171·30	20	15	—	Ti	
4274·75	2	no	4274·93	75	30	50	Cr	Eclipse line undoubtedly due to Cr.
4285·16	2	no						
4286·17	2	no	4286·0	6				
4288·04	2	no	4287·91	25	25	—	Ti	
4289·24	2	no						
4290·38	2	yes	4290·34	40	20	65	Ti	Line in Kensington photograph probably compounded of Cr 4289·89 and Ti 4290·38
4291·11	3	no	4291·11	12	12	—	Ti	
4291·28	2	no						
4294·20	2	yes	4294·41	70	—	50	Fe	Probably due to Fe 4294·30 + Ti 4294·20, but there is more evidence for Ti than Fe.
4298·83	2	no						
4299·80	2	no						
4300·21	3	yes	4300·36	60	20	50	Mn	Evidence in favour of Mn origin very weak, that for Ti very strong.

4300·73	2	no						
4301·16	2	no						
4302·09	2	yes	4301·96	40	15	—	Ti	
4306·08	4	no						
4313·03	3	yes	4312·99	40	25	20	Ti	
4315·14	3	yes	4315·28	40	30	45	Ti, Fe	Eclipse line probably Ti 4315·14 + Fe 4315·26.
4338·08	4	yes	4337·99	25	20	50	Ti, Sr?	Evidence for Sr negligible.
4341·53	2	yes	—	—	—	—	—	Probably masked by Hγ.
4344·45	2	yes	4344·42	50	25	30	Ti	
4367·84	2	yes	4367·64	25	15	25	Fe	Probably due to Ti 4367·84 + Fe 4367·68, but evidence for Ti much better than that for Fe.
4394·22	2	no						
				Grating spectra.				
				"Flash" I.	"Flash" II.			
4395·20	3	yes	4395·27	50	50	70	Ti	
4417·88	3	yes	4417·80	18	30	45	Ti	
4427·27	2	no	4427·4	12	12	30	Ti, Fe	Possibly due to Fe 4427·44 + Ti 4427·27, but evidence for Fe greater than that for Ti.
4443·98	5	yes	4444·0	40	35	70	Ti	
4449·31	2	no						
4450·65	2	yes	4450·6	18	20	50	Ti?	
4453·49	2	no						
4464·62	2	yes	4464·6	6	12	25	Ti?	
4468·66	5	yes	4468·8	50	30	60	Ti	
4501·45	5	yes	4501·44	35	35	70	Ti	
4512·91	3	no						
4518·20	3	no	4518·0	—	5			
4522·97	2	no	4522·7	15	25	40	Ti	Eclipse line undoubtedly due, in the main, to enhanced Fe 4522·69.

Solar Lines of Intensity 2 or greater, ascribed by Rowland to Ti only—*continued*.

Solar – Ti lines λ (Rowland).	Int. in sun.	If enhanced line.	Eclipse.					Remarks.
			Frost.			Kensington.	Frost's origin.	
			Adopted wave-length.	Intensity. Max. 500. Prism spectra.		Int. Max. 100.		
				"Flash" II.	Cusp II.			
4527·49	3	no						
4533·42	4	no						
4534·95	4	no						
4535·74	3	no	—	—	—	} 20		λ of eclipse line 4535·9.
4536·09	2	no	—	—	—			
4536·22	2	no						
4544·86	3	no	—	—	—	30		
4548·94	2	no						
4552·63	2	no						
4555·66	3	no						
4563·94	4	yes	4563·94	30	40	75		
4572·16	6	yes	4572·16	45	45	70		
4617·45	3	no						
4623·28	2	no						

In the above list of solar-titanium lines there are thirty-three which are not "enhanced" in the spark spectrum. It will be seen that twenty-three of these—or 70 per cent.—have no corresponding line (within 0·3 tenth-metre) in Professor Frost's record of eclipse lines. Of the nine eclipse lines in the table which do agree approximately in position with unenhanced titanium lines, two are with certainty due to other metals, and in another case there is more evidence for an iron origin than one of titanium. These are indicated in the column for remarks. The remainder are nearly all lines of insignificant intensity.

Of the twenty "enhanced" lines of titanium which occur in the list, nineteen have corresponding lines in Professor Frost's eclipse spectra, the remaining one being also possibly represented, but it falls so near the strong Hγ line that it might be easily masked. Not only are they represented in the eclipse spectra, but in nearly every case the corresponding eclipse line is a prominent one, as will be gathered at once from a glance at the tabular list given.

Professor Frost summarily dismisses the significance of the enhanced lines of titanium in the eclipse spectra, because "most of them occur as quite strong lines in the ordinary dark line spectrum, and hence would be expected to appear in the reversing layer, as they do." But if he would expect one line of a certain solar intensity, he should expect all lines due to the same element which are of an equal solar intensity, to appear in the eclipse spectra. Yet another glance at the foregoing table will show that many of the titanium lines strongly represented in the eclipse spectra are of the lowest intensity in the Fraunhofer spectrum, and that if lines of a certain solar intensity be considered, those that are enhanced lines appear in the eclipse spectra, whereas the unenhanced ones do not.

In this comparison no account has been taken of the relative intensities of the lines in the titanium spectrum itself. Hasselberg has published* a lengthy list of titanium arc lines, and in the region covered by the eclipse spectra records about 250. To compare all these with the eclipse lines would take too much time and space, nor is it necessary. To show the difference in behaviour in the eclipse spectra of the enhanced and the strongest arc lines, two separate lists of titanium lines have been made. The first, which follows immediately, contains all the enhanced lines which occur in Hasselberg's arc list, and the intensities of Professor Frost's and the Kensington eclipse lines which correspond within 0·3 tenth-metre are also given.

* 'Kongl. Svenska Vetenskaps Akad. Handl.,' vol. 28, No. 1, 1895.

Enhanced Lines of Titanium recorded by Hasselberg in Arc Spectrum, and their behaviour in Eclipse Spectra.

Enhanced lines in Hasselberg's Ti arc spectrum.		Eclipse.					Remarks.
		Frost.			Kensington.	Frost's origin.	
		Adopted wave-length.	Intensity max. 500. Prism spectra.		Int. max. 100.		
λ.	Int. Max. 8.		"Flash" II.	Cusp II.			
4025·26	2					—	Undoubtedly due to Ti.
4028·48	3	4028·28	35	20	25		
4053·96	3	4053·9	12	—	30	Fe, Ti	Probably due to enhanced Ti 4053·98 + enhanced V 4053·80.
4055·18	5	4054·98	40	?	—	Fe	Evidence for Ti stronger than that for Fe.
4161·67	2	4161·81	80	5	35		
4163·80	5	4163·86	50	12	40	Ti, Cr	Evidence for Cr weak.
4172·04	4	4172·15	80	15	35	Ti, Fe	
4173·66	3	4173·75	50	?	45	—	Probably due to enhanced Fe 4173·52 + enhanced Ti 4173·70.
4174·20	2						
4290·37	5	4290·34	40	20	65	Ti	Line in Kensington photograph probably compounded of Cr 4289·89 and Ti 4290·38.
4294·28	6	4294·41	70	—	50	Fe	Probably due to Fe 4294·30 + Ti 4294·20. More evidence for Ti than Fe.
4300·19	6	4300·36	60	20	50	Mn	Evidence for Ti origin far outweighs that for Mn.
4302·08	5	4301·96	40	15	—	Ti	
4313·01	6	4312·99	40	25	20	Ti	
4315·15	4	4315·28	40	30	45	Ti Fe	Probably due to Ti 4315·14 + Fe 4315·26.

4316·96	4	4316·79	12	6			
4321·12	3	4321·06	60	50	50	Sc	Probably due to enhanced Ti 4321·20 + Sc 4320·91.
4330·85	3	4330·71	30	?	25		
4338·05	6	4337·99	25	20	50	Ti, Sr?	Evidence for Sr negligible.
4341·51	3	—	—	—	—	—	Probably masked by Hγ.
4344·47	3	4344·42	50	25	30	Ti	
4350·99	2						
4367·81	3	4367·64	25	15	25	Fe	Probably due to Ti 4367·84 + Fe 4367·68. Better evidence for Ti than Fe.
4374·97	2	4374·8	60	30	70	—	Probably due to enhanced Ti 4374·90 + Sc 4374·63.
4387·00	2						
			"Flash" I	"Flash" II			
4395·17	7	4395·20	50	50	70	Ti	
4395·99	3						
4399·92	5	4399·9	7	—	55	Ti, Cr	
		4400·3	25	30		Sc	
4417·88	5	4417·80	18	30	45	Ti	
4464·60	3	4464·6	6	12	25	Ti?	
4468·65	6	4468·8	50	30	60	Ti	
4488·47	3						
4501·43	6	4501·44	35	35	70	Ti	
4534·15	5	4534·2	40	60	75	Ti, Co	Probably due solely to Ti.
4549·79	6	4549·9	40	55	75	Ti, Co	Probably due to enhanced Fe 4549·64 + enhanced Ti 4549·81.
4563·94	5	4563·94	30	40	75	Ti	
4572·15	6	4572·16	45	45	70	Ti	
4590·11	4	4590·1	12	10	30		

Reference to the above table will show that the "arc" intensities of the enhanced lines vary from 2 to 7 (maximum intensity adopted is 8), and that nearly throughout Frost records corresponding eclipse lines, the majority of the latter being quite prominent.

The second list consists of the very strongest arc lines (intensity 7 and 8) which are not enhanced in the spark spectrum. Here again the intensities of the corresponding eclipse lines, if any, are quoted.

Strongest Arc Lines of Titanium, and their relation to Eclipse Lines.

Titanium arc. (Hasselberg.)		Eclipse.				
		Frost.			Kensington.	
			Intensity. Max. 500.			
λ.	Int. Max. 8.	Adopted wave-length.	Prism spectra.		Int. Max. 100.	Frost's origin.
			"Flash" II.	Cusp II.		
4186·27	7	4186·3	—	5		
4286·15	7	4286·0	6			
4287·55	7	—	—	—	10	
4289·23	7					
4295·91	7	4295·98	7	15		Cr, Ti, Ni.
4298·82	7					
4300·73	7					
4301·23	7					
4306·07	8					
4314·95	7					
4318·83	7	4319·02	20	12		Ca, Mn?
			Grating spectra.			
			"Flash" I.	"Flash" II.		
4427·28	8	4427·4	12	12	30	Ti, Fe.
4457·59	7	4457·8	—	5	—	Ti, V, Zr, Mn.
4518·18	7	4518·0	—	5	10	
4533·42	7					
4534·97	7					
4544·83	7	—	—	—	30	
4548·93	7					
4552·62	7					
4617·41	7					

Here, it will be observed, there are only seven out of the twenty strongest titanium arc lines which have possibly corresponding lines in Frost's eclipse spectra. To three of these eclipse lines he assigns no origin; to the others he gives compound origins, three of them involving titanium. In no case is the corresponding eclipse line as

Solar Lines of Intensity 2 or greater, ascribed by Rowland to Fe only. (λ 4500 to λ 4600.)

Solar — Fe lines λ (Rowland).	Int. in sun.	Int. in arc spectrum (K. & R).	If enhanced line.	Eclipse.					Remarks.
				Frost.			Kensington.	Frost's origin.	
				Adopted wave-length.	Intensity. Max. 500. Grating spectra. "Flash" I.	Intensity. Max. 500. Grating spectra. "Flash" II.	Int. Max. 100.		
4508·46	4	1	yes	4508·4	7	15	50	Fe?	
4517·70	3	4	no	4518·0	—	5			
4520·49	3	1	yes	4520·4	8	17	30	Fe?	
4525·31	5	6	no	4525·0	—	7	—	Fe	
4528·80	8	10	no	4528·6	—	5	30	Fe	Strongest line in this region of the iron spectrum.
4531·33	5	8	no						
4531·80	2	4	no						
4548·02	3	8	no						
4549·64	2	4	yes	4549·9	40	55	75	Ti, Co	Probably due to enhanced Fe 4549·64 + enhanced Ti 4549·81.
4550·94	2	—	no						
4560·27	2	2	no						
4574·90	2	4	no						
4584·02	4	2	yes	—	25	35	70	Fe	
4587·31	2	4	no						
4592·84	4	8	no						
4595·54	2	4	no						
4596·25	2	2	no						
4598·30	3	6	no						

strong as the majority of those which are the representatives of the enhanced lines.

In the case of iron, all the well-enhanced lines are represented in the eclipse spectra, but they are not of quite the same prominence as the titanium enhanced lines. They are, so far as their intrinsic intensities in the iron arc spectrum are concerned, quite insignificant lines as compared with the majority of other iron lines, but their importance lies in the fact that they are a class of lines of special behaviour, being relatively stronger in the spark spectrum than in the arc. In the eclipse spectra they are undoubtedly represented by stronger lines than are the *great majority* of unenhanced iron lines, however strong the latter may be in the iron arc spectrum itself.

Owing to the great number of iron lines in the solar spectrum, a comparison similar to that given for titanium over the whole region covered by the eclipse lines would necessitate the compilation of a very lengthy list. But whatever evidence there is either one way or another should be revealed by a comparison over a limited region, so it is proposed to take that between λ 4500 and λ 4600, since the proportion of enhanced to unenhanced iron lines is there greatest, and therefore a better opportunity is afforded of a fair comparison of the behaviour of the two classes of lines. The table given on p. 187 is arranged in exactly the same way as in the case of titanium, with the exception that there is an additional column showing the intensities in the arc spectrum, as recorded by Kayser and Runge.

It will be seen that the unenhanced lines are here also unrepresented in the eclipse spectra, with the possible exception of three, which are recorded as very weak lines in one of Professor Frost's spectra, but are missing from the other. All the enhanced lines, however, although they have the weakest arc intensities, appear in each of the eclipse spectra, and have abnormal intensities compared with those corresponding to the unenhanced lines. It must be pointed out that only four of the nine enhanced iron lines in the part of the spectrum considered appear in the above list, because they are the only ones which are given in Rowland's origins for solar lines. At least four out of the remaining five—those at $\lambda\lambda$ 4515·51, 4522·69, 4556·10, 4576·51, probably correspond to the solar lines 4515·51, 4522·69 (or possibly 4522·80), 4556·06, and 4576·51, to which Rowland has assigned no origin. The outstanding line at λ 4541·40 is doubtfully present in the solar spectrum. The first three of these five have corresponding lines in the eclipse record; the other two have not. In the Kensington reductions of eclipse spectra there are, however, lines agreeing (within 0·3 tenth-metre) with every one of the enhanced lines mentioned.